MD-Vol. 84, Mechanical Behavior of Advanced Materials
ASME 1998

MEMS-BASED TEST STRUCTURES FOR IC TECHNOLOGY

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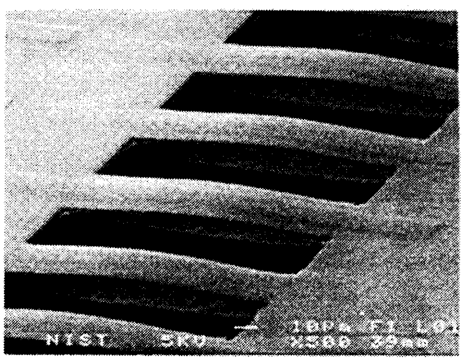
INTRODUCTION: As Integrated Circuit (IC) device sizes shrink, intrinsic and thermo-mechanical stress in interconnects is an ever increasing reliability concern. Increasing device density leads to more interconnect layers and hence, greater probability of stress related failure through mechanisms such as electromigration, delamination and voids. Current state-of-the-art IC technology uses 5 interconnect layers. According to the 1997 SIA Roadmap, that number is expected to increase to 9 by the year 2012 [1]. As a result, methods to measure, model and reduce stresses in interconnects are needed to manufacture reliable, future generation IC's.

Paramount to the determination of stress is the measurement of strain. To date, strain measurement techniques using MEMS surface micromachining technology have focussed primarily on the measurement of strain in homogenous thin films [2,4], specifically, polysilicon films [3-6]. However, due to the CMOS layer structure, the applicability of many of these strain measurement techniques to production IC technology is limited. In addition, the need to measure strains in multi-layer systems adds an additional degree of complexity.

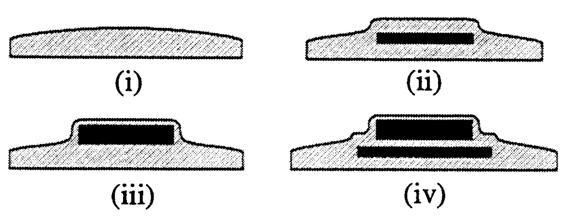
We have developed MEMS-based test structures, compatible with the standard CMOS process, for the measurement of compressive strain in IC interconnect layers. These structures employ an extension of the simple beam buckling method in [2,3].

A mathematical formulation for the determination of interconnect strain has been developed for this application. Strain is calculated from measurements of the maximum beam deflection and the length between the fixed ends of the buckled beam. The small displacement theory formulation used here is compared to that derived from the exact solution to the beam deflection equation, the Elastica. Accuracy of the approximate solution and guidelines for its usage are discussed.

TEST STRUCTURE DESIGN/FABRICATION: Fixed-Fixed Beam (FFB) test structures of varying length were fabricated in a 1.2μm CMOS process available through the MOSIS Service [http:\\www.mosis.org]. The structures were mechanically released with an additional post-process isotropic micromachining step [7,8]. Each element of the array consists of a set of FFB test structures, as shown in Fig. 1a.



(a)



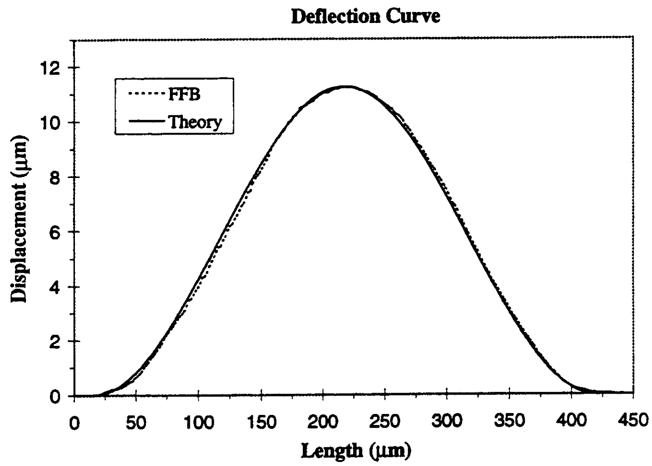
(b)

Figure 1. (a) *SEM micrograph showing composite FFB test structures, and* (b) *beam cross section illustrating the composite nature of the test structures.*

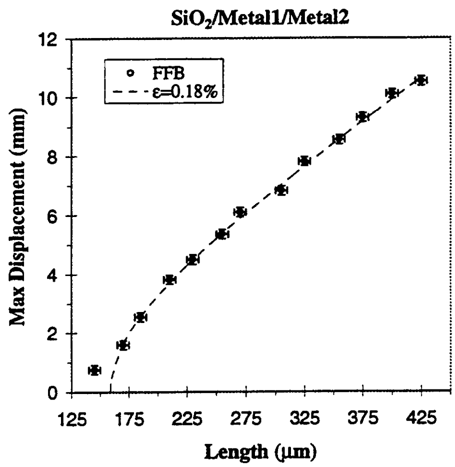
The beams vary in length from 50 μm to 400 μm in 25 μm increments. An array of varying length beams is used to ensure strain measurements are independent of test structure length. However, as is the case with the critical buckling length method [5], an array of varying length beams is not required, provided the cross section geometry for each composite beam is known.

Cross sections for the beams, shown in Fig. 1b, differ in both composition and geometry. Beams (i) through (iv) in Fig. 1b consist of SiO_2; SiO_2, and Al from the first metalization layer (SiO_2/Metal1); SiO_2 and Al from the second metalization layer (SiO_2/Metal2); and SiO_2, and Al from both metalization layers (SiO_2/Metal1/Metal2), respectively.

RESULTS: Measurements of deflection profiles were taken from an array of composite FFB test structures using an optical profilometer. Layer thickness and cross section geometry were obtained from SEM measurements. In general, deflection profiles from these test structures are in good agreement with theoretical prediction, see Fig. 2a.



(a)



(b)

Figure 2. (a) *Measured deflection curve compared to theory, and* (b) *Comparison of a SiO_2/metal1/metal2 FFB test structure with theory for ε=0.18%.*

Compressive strains from these composite test structures have been obtained from every set in the array. Values are shown to be in good agreement with theory. Regardless of beam length, the measurements of the maximum displacement are consistent with a constant strain value. In Fig. 2b, the displacements for the SiO_2/metal1/metal2 test structures are plotted along with values predicted from theory for a strain of $\varepsilon = 0.18\%$.

The strains in the individual interconnect layers have been obtained by analyzing the measurement results, and the stress calculated from constitutive relations.

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